JC10 Rec'd PCT/PTO 12 FEB 2002

U S DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE		ATTORNEY'S DOCKET NUMBER KOGAN=4
TRANMITTAL LETTER TO THE UNITED STATES DESIGNATED/ELECTED OFFICE (DO/EO/US) CONCERNING A FILING UNDER 35 U.S.C. 371		U S APPLICATION NO (If known,see 37 CFR 1 5) 10/049433
INTERNATIONAL APPLICATION NO. PCT/IL00/00483	INTERNATIONAL FILING DATE 08 August 2000	PRIORITY CLAIMED 12 August 1999
TITLE OF INVENTION REACTION CHAMBER WITH A PROTECTED SURFACE		
APPLICANT(S) FOR DO/EO/US **Abraham KOGAN et al.**		

Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information

1. [X] This is a **FIRST** submission of items concerning a filing under 35 U.S C 371
2. [ ] This is a **SECOND** or **SUBSEQUENT** submission of items concerning a filing under 35 U S C 371
3. [X] This is an express request to begin national examination procedures (35 U S.C 371(f)) at any time rather than delay examination until the expiration of the applicable time limit set in 35 U S.C 371(b) and PCT Articles 22 and 39(1)
4. [X] The US has been elected in a Demand by the expiration of 19 months from the priority date (PCT Article 31)
5. [X] A copy of the International Application as filed (35 U.S.C 371(c)(2))
   a [ ] is attached hereto (required only if not transmitted by the International Bureau)
   b [X] has been communicated by the International Bureau.
   c [ ] is not required, as the application was filed in the United States Receiving Office (RO/US).
6. [ ] An English language translation of the International Application as filed (35 U.S.C 371(c)(2))
7. [X] Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C 371(c)(3))
   a [ ] are transmitted herewith (required only if not transmitted by the International Bureau)
   b [ ] have been communicated by the International Bureau.
   c [ ] have not been made, however, the time limit for making such amendments has NOT expired.
   d [X] have not been made and will not be made
8. [ ] An English language translation of the amendments to the claims under PCT Article 19 (35 U S C 371(c)(3))
9. [ ] An oath or declaration of the inventor(s) (35 U S C. 371(c)(4)).
10. [ ] An English language translation of the annexes to the International Preliminary Examination Report under PCT Article 36 (35 U S.C 371(c)(5))

Items 11. to 16. below concern document(s) or information included:

11. [ ] An Information Disclosure Statement under 37 CFR 1 97 and 1 98
12. [ ] An Assignment document for recording A separate cover sheet in compliance with 37 CFR 3 28 and 3.31 is included
13. [ ] A FIRST preliminary amendment
    [ ] A SECOND or SUBSEQUENT preliminary amendment
14. [ ] A substitute specification
15. [ ] A change of power of attorney and/or address letter
16. [X] Other items or information:
    [X] Courtesy copy of the International Application as filed.
    [X] Courtesy copy of the first page of the International Publication (WO 01/12314)
    [X] **Courtesy copy of the International Preliminary Examination Report with annexes containing claims 1-17 to be substituted for original claims 1-14 for examination in this case.**
    [X] Formal drawings, 7 sheets, Figures 1-7
    [X] Courtesy Copy of the International Search Report
    [X] Application Data Sheet

[X] The application is (or will be) assigned to YEDA RESEARCH AND DEVELOPMENT CO. LTD., whose address is _Weizmann Institute of Science, P O. Box 95, 76100 Rehovot, Israel.

JC11 Rec'd PCT/PTO 12 FEB 2002

U.S. APPLICATION NO (If known, see 37 CFR 1 5)	International Application No	Attorney's Docket No
10/049433	PCT/IL00/00483	KOGAN=4

17. [xx] The following fees are submitted

BASIC NATIONAL FEE (37 CFR 1.492 (a)(1) –(5):

Neither international preliminary examination fee (37 CFR 1 482) nor international search fee (37 CFR 1 445(a)(2)) paid to USPTO and International Search Report not prepared by the EPO or JPO................**$1040.00**

International preliminary examination fee (37 CFR 1 482) not paid to USPTO but International Search Report prepared by the EPO or JPO **$890.00**

International preliminary examination fee (37 CFR 1.482) not paid to USPTO but international search fee (37 CFR 1 445(a)(2)) paid to USPTO **$740.00**

International preliminary examination fee paid to USPTO (37 CFR 1 482) but all claims did not satisfy provisions of PCT Article 33(1)-(4)................**$710.00**

International preliminary examination fee paid to USPTO (37 CFR 1.482) and all claims satisfied provisions of PCT Article 33(1)-(4). **$100.00**

CALCULATIONS PTO USE ONLY

				CALCULATIONS	PTO USE ONLY
ENTER APPROPRIATE BASIC FEE AMOUNT =				$ 890.00	
Surcharge of **$130.00** for furnishing the oath or declaration later than [ ] 20 [X] 30 months from the earliest claimed priority date (37 CFR 1 492(e))				$ 130.00	
Claims as Originally Presented	Number Filed	Number Extra	Rate		
Total Claims	21 - 20	1	X $18 00	$ 18.00	
Independent Claims	2 - 3		X $84.00	$	
Multiple Dependent Claims (if applicable)			+$280 00	$ 280.00	
TOTAL OF ABOVE CALCULATIONS =				$1,318.00	
Claims After Post Filing Prel Amend	Number Filed	Number Extra	Rate		
Total Claims	- 20		X $18.00	$	
Independent Claims	- 3		X $84 00	$	
TOTAL OF ABOVE CALCULATIONS =				$1,318.00	
Reduction of ½ for filing by small entity, if applicable. Applicant claims small entity status. See 37 CFR 1.27.				$ 659.00	
SUBTOTAL =				$ 659.00	
Processing fee of **$130.00** for furnishing the English translation later than [ ] 20 [ ] 30 months from the earliest claimed priority date (37 CFR 1 492(f))				$	
TOTAL NATIONAL FEE =				$ 659.00	
Fee for recording the enclosed assignment (37 CFR 1.21(h)). The assignment must be accompanied by an appropriate cover sheet (37 CFR 3.28, 3 31) **$40.00** per property +				$	
TOTAL FEES ENCLOSED =				$ 659.00	
				Amount to be: refunded	$
				charged	$

a. [ ] A check in the amount of $__________ to cover the above fees is enclosed.
b. [X] Credit Card Payment Form (PTO-2038), authorizing payment in the amount of $ 659.00, is attached.
c. [ ] Please charge my Deposit Account No **02-4035** in the amount of $__________ to cover the above fees A duplicate copy of this sheet is enclosed
d. **[XX]** The Commissioner is hereby authorized to charge any additional fees which may be required, or credit any overpayment to Deposit Account No **02-4035** A duplicate copy of this sheet is enclosed

NOTE: Where an appropriate time limit under 37 CFR 1.494 or 1.495 has not been met, a petition to revive (37 CFR 1.137(a) or (b)) must be filed and granted to restore the application to pending status.

SEND ALL CORRESPONDENCE TO

BROWDY AND NEIMARK, P.L.L.C.
624 NINTH STREET, N.W., SUITE 300
WASHINGTON, D.C. 20001
TEL: (202) 628-5197
FAX: (202) 737-3528

Date of this submission: **February 12, 2002**

[signature]
SIGNATURE
Roger L. Browdy
NAME
25,618
REGISTRATION NUMBER

REACTION CHAMBER WITH A PROTECTED SURFACE

FIELD OF THE INVENTION

This invention relates to reaction chambers having ingress and egress openings, and a surface to be protected from contact with components of the reaction, in particular, for use in solar energy receivers for the protection of their transparent windows.

BACKGROUND OF THE INVENTION

Extensive work has been directed in recent years to the development of efficient ways to use concentrated solar radiation as the energy source driving endothermic chemical reactions, such as for example, the production of hydrogen and carbon black by pyrolysis of methane using solar energy for process heat.

One type of a solar reactor which may be used for such a purpose is a "*surface receiver*" wherein concentrated solar radiation is introduced through the receiver's aperture into its cavity, while the reactants flow through tubes staggered in different arrangements inside the cavity. In such a type of reactor, the radiation is absorbed at the surface of the tubes, and the heat required for carrying out the reaction is transferred through the tubes' walls to reactants flowing inside the tubes. However, such reactors are rather bulky and their working temperature is restricted by thermal limitations imposed by the tube material and the temperature gradient across the tube walls.

In an attempt to overcome these difficulties, another type of solar reactor has been developed, called a "*volumetric receiver*". In such a receiver, the reactants are directly introduced into the reactor's chamber where they themselves are exposed to direct concentrated solar radiation that enters the

chamber through a transparent window. The use of such reactors eliminates the need for incorporating tubes, whereby the overall heat transfer efficiency of the process is increased. An example of such a solar volumetric receiver, designed for solar heating of compressed air, was described by J. Karni et al., Proc. ASME/JSME/JSES Int. Solar Eng. Conf., 1: 551-556, 1995.

However, in many chemical reactions some of the reactants and/or products of the reaction are in the form of particles. This fact presents a problem when a volumetric receiver is considered for such a reaction, because particles will eventually be deposited on the surface of the transparent window of the receiver, reducing its transparency. Moreover, the radiation that will be absorbed by these particles will cause their immediate heating up, leading to the generation of hot spots at the window, and consequently to the disintegration of the window.

Many attempts have been made to overcome this problem, and the following are typical examples of such attempts described in the literature.

Litterst (Proc. 6th Inst. Symp. On Solar Thermal Concentrating Technologies, Almeria, 1992, pp. 359-369) experimented with a vertical fluidized bed reactor, having a transparent window mounted on a cylindrical wall of the reactor. Reactants are introduced in the reactor in a primary flow parallel to the window and an air curtain is provided parallel to the primary flow direction adjacent to the window's inner surface to protect it against contact with solid particles. This attempt failed as the thin air curtain adjacent the window's inner surface detached therefrom under the influence of the primary flow of reactants, a short distance from its entry port. An attempt to remove the window from the primary flow by mounting it on a T-type branch did not fair much better. Solid particles were transported in "pulselike eruptions" from the fluidized bed towards the window. An attempt to decelerate fast particles by injecting compressed air through radially positioned

tubes near the window's inner surface showed that huge amounts of air, in the order of 50% of the primary reactant flowrate, were required to keep the window free of contact with solid particles.

A cylindrical volumetric solar reactor with a transparent window mounted adjacent a front end of the reactor's cavity and spaced away therefrom by an aperture plane, is described in the Paul Scherrer Institute, Final Report to Bundesamt für Energie - Contract EF-REN (92) 033, p. 149. Here a suspension of ZnO powder in natural gas is injected into the reactor's cavity in a tangential primary flow adjacent a back end thereof. The products of reaction leave the cavity through a tangential outlet port located at the front end thereof. The window is kept clean of suspended particles by means of two auxiliary flows of gas, one injected tangentially at the window and one injected radially at the aperture plane. The design was optimized to minimize the auxiliary flows while keeping the window clear of particles, however, the total auxiliary gas flowrate was 83% of the primary gas flowrate. Such a high auxiliary gas flowrate can absorb the heat received by the reaction cavity and thereby interfere with the desired reaction.

A solar receiver described in WO 96/25633 comprises an axially symmetric annular chamber with an inner wall constituted by a frusto-conical or cylindrical quartz window through which solar radiation is admitted into the chamber. A fluid mixture in the form of a particle suspension is injected into the chamber adjacent and tangentially to an end of its outer wall and the products of the reaction are withdrawn near an opposite end of the outer wall and tangentially thereto, whereby the suspension flows around the inner wall in a whirling manner. Due to the centrifugal force acting on the whirling particle suspension, contact between particles and the window is minimized. To cool the window, the inner surface of the window is swept with a particle-free pressurized fluid.

SUMMARY OF THE INVENTION

An object of the present invention is to provide a novel solution for efficient protection of a surface in a reaction chamber.

In accordance with one aspect of the present invention, there is provided a method for protecting a surface at one end of a reaction chamber having a longitudinal axis transverse to said surface, the method comprising introducing a primary flow of reactants into the chamber in a manner whirling around said longitudinal axis, and withdrawing reaction products at an opposite end of the reaction chamber in a flow along the longitudinal axis, whereby said primary flow and said flow of reaction products approximate a free vortex flow, and introducing into the chamber a secondary protecting flow directed from a periphery of said surface towards said longitudinal axis, enabling thereby a pressure created by said vortex flow to keep said secondary flow adjacent said surface substantially over its entire area.

By virtue of the method of the present invention, a negative radial pressure gradient created by the vortex flow increases steeply towards said longitudinal axis and, therefore, towards the center of the surface to be protected, acting as an anchor to pull the secondary flow from the periphery to the center as a boundary layer without separation. This allows for the protection of the surface by the secondary flow with a significantly lower flowrate than that of the primary flow.

A further advantage of the present invention is that the path length of the whirling primary flow across the chamber is substantially extended when compared with the chamber's axial dimension, thereby contributing to achieving higher thermal and chemical conversion efficiencies, since the vortex flow provides strong mixing of the reactants. This mixing effect also helps in preventing strong local temperature gradients in the primary flow, which could lead to flow instability due to buoyancy.

The method of the present invention is particularly useful for reaction chambers wherein a reaction is carried out in which at least one component, a reactant, a product or a catalyst, is in a particulate form. The term "*particulate form*" as used in the present application denotes primarily a solid material being in the form of powder or particles, but may relate also to materials being in the form of liquid droplets.

The secondary protective flow may be an inert gas, but preferably is one of the reactants or products, or a mixture thereof, provided that it does not contain particles and that it is not heated in the chamber to the extent that will prevent its use in protecting the transparent window as desired, or to the extent that will cause the reaction to proceed in the secondary flow to a significant degree. Although by a preferred mode of the invention the secondary flow is in the gaseous phase, it should be understood that within the scope of the present invention it may also be in a liquid phase.

In accordance with another aspect of the present invention, there is provided a reaction chamber having a surface to be protected, and ingress and egress means designed to provide the primary and secondary flows described above. In particular, the reaction chamber has a primary ingress means adapted for introducing into the chamber the primary flow along a circumference of the chamber at a location axially spaced from the surface. It is preferable in this case that the surface and the chamber are substantially symmetric about the longitudinal axis of the chamber. It is also preferable that the primary ingress means are capable of introducing into the chamber the primary flow essentially tangentially to the chamber's circumference to achieve a whirling flow. Appropriate ingress means are therefore typically annular and may be in the form of an impeller-like ring. It may be advantageous if the primary ingress means are capable of delivering the primary flow into the chamber in the form of a substantially conical jet, flowing away from the surface. The primary

ingress means may be designed to introduce the flow in a converging or diverging manner.

The reaction chamber also has secondary ingress means adapted for introducing into the chamber the secondary flow in close proximity to a periphery of the surface. It is preferable that the secondary ingress means are capable of introducing the secondary flow essentially radially relative to the longitudinal axis. Egress means for withdrawing the reaction products are preferably in the form of an outlet port located along the longitudinal axis of the chamber at its end opposite to the surface, thus promoting the contained whirling motion that approximates a free vortex flow. Preferably, the outlet port is narrow relative to the dimension of the surface to be protected. The outlet port of the chamber may be connectable to any suitable downstream equipment, e.g. conventional gas-solid separation equipment, heat-exchanger or any other equipment as known *per se* in the art.

A preferred embodiment of the method and reaction chamber of the present invention concerns their use in a volumetric solar receiver having a reaction chamber and provided with effective protection of a transparent window located in a wall thereof and adapted for admitting concentrated solar radiation therein. The secondary flow according to this embodiment of the invention should preferably be a poor absorber of solar radiation and is, preferably, a non-absorbing fluid. In addition to being a protective layer, when the secondary flow is introduced at a relatively low temperature into the chamber, it will cool an inner surface of the window mainly by convecting the heat therefrom, whereby thermal loads to which the window is subjected are reduced.

The window may be planar, concave or convex, or rather it may be in the form of any appropriate surface of revolution.

The reaction chamber may have an interior design capable of directing the primary flow in a desired manner, for example, the interior wall of the chamber may be shaped so that the primary flow entering the chamber as a conical jet flows along the chamber's interior wall. Heating of the primary flow is greatly enhanced by heat transfer from the chamber's interior wall.

An initial widening of the chamber in the flow direction of the primary flow renders the chamber's diameter larger than the window's diameter and, thereby, makes the chamber's shape closely approximate a black body radiation cavity.

The receiver's performance, and particularly its performance during the start up of the reaction carried out therein, may be improved by introducing into the chamber additional solar radiation absorbing particles. These particles are adapted to serve as solar radiation absorbents, allowing a rapid elevation of the temperature of the primary flow in the chamber. These solar radiation absorbing particles may be introduced as a mixture together with the primary flow, or separately, via ingress means dedicated for their introduction into the chamber.

The receiver may further be provided with third ingress means in a region exterior to the receiver chamber, in close proximity of the transparent window, to introduce therein a cooling fluid in an essentially radial or tangential flow.

DESCRIPTION OF THE DRAWINGS

For better understanding, the invention will now be described by way of example only, with reference to a specific example being the pyrolysis of methane. It should be understood that this example is provided for demonstrating the invention, but in no way is the invention limited to this specific process.

Fig. 1 is a general schematic view of a reaction chamber which is the subject of the present invention;

Fig. 2 is a schematic view of an impeller-like ring for use in the reaction chamber of Fig. 1; and

Figs. 3 to 7 are cross-sectional views of the reaction chamber of Fig. 1 according to different embodiments of the present invention.

DESCRIPTION OF PREFERRED EMBODIMENTS

Fig. 1 shows a reactor 100, according to the present invention, that has a reaction chamber 101 with a longitudinal axis of symmetry 103. The reaction chamber 101 has a transparent window 105 disposed at its front end and orientated perpendicularly to the longitudinal axis 103. The reactor 100 has a primary ingress means in the form of an impeller-like ring 110 (shown in Fig. 2) which is capable of introducing into the chamber 101 a primary flow 109 of reactants in a manner whirling around the longitudinal axis 103, and a secondary ingress means 106 capable of introducing into the chamber a secondary protecting flow 113 directed from an inner periphery 115 of the window 105 towards the longitudinal axis 103. At a rear end, the reaction chamber 101 has an outlet 107 disposed along the axis 103 and capable of withdrawing reaction products from the chamber 101.

For the purpose of the description, the present reactor 100 is described for carrying out a process defined by the following reaction:

$$CH_{4(g)} \rightarrow C_{(s)} + 2H_{2(g)}$$

in which methane is pyrolyzed by the heat of concentrated solar radiation 111 introduced into the chamber 100 via the transparent window 105, to form carbon and hydrogen.

Methane as a primary flow 109 is introduced into the reaction chamber 101 in a significantly tangential manner through the impeller-like ring 110, and

proceeds to whirl around the longitudinal axis 103. The primary flow 109 is heated by concentrated solar radiation 111 that enters the chamber via the window 105, to a temperature at which the methane will split into hydrogen and carbon black. The carbon black particles suspended in the whirling fluid mixture inside the chamber 101 render the flow 109 opaque to the radiation 111, thereby enhancing its heating and, consequently, increasing the yield of the methane pyrolysis products, which are them withdrawn from the reaction chamber 101 via the outlet 107, whereby the primary flow 109 and the flow of reaction products approximate a free vortex flow.

After initial decomposition of some methane, carbon black particles are formed which directly absorb the solar radiation 111, and thereby considerably enhance the conversion obtained in the process of methane pyrolysis. Further enhancement of the reactor's performance, especially in the start up stage of the process, may also be achieved by introducing solar radiation absorbing particles into the chamber 101, together with the primary flow 109. Preferably these particles are carbon particles that are introduced together with the methane until a sufficient amount of carbon particles produced by the methane decomposition are present in the chamber 101. These solar radiation absorbing particles may be introduced as a mixture with the methane through the primary ingress means 110, or via a separate ingress means (not shown) dedicated to their introduction into chamber 101.

For the protection of the window 105 from contact with the hot components of the reaction, in particular, from the carbon black particles released therefrom, the secondary flow 113 is introduced radially via the secondary ingress means 106 at the window's inner periphery 115 to provide a protective boundary layer 117. This secondary flow 113 is preferably in the gas phase and may be an inert gas or methane, hydrogen or a mixture thereof. When no inert gas is used, there is no need for an additional recovery operation

to separate the inert gas from the reaction products, downstream from the reactor 100. On the other hand, if methane is used as the secondary flow 113, attention must be given that its flowrate near the window 105 be high enough to ensure that its temperature will not exceed the temperature at which pyrolysis will start, giving rise to the undesired formation of carbon black particles in the vicinity of window 105.

The following synergetic co-operation of the vortex flow, consisting of the primary flow 109 and the flow of reaction products, and the secondary flow 113, prevents carbon black particles in the chamber 101 from reaching the window 105. The vortex flow of the fluid mixture produces a negative radial pressure gradient in the chamber 101, the pressure being highest at a periphery 116 thereof and lowest adjacent the chamber's axis of symmetry 103. This negative radial pressure gradient is essentially balanced by the centrifugal force of the whirling vortex flow. By extracting the reaction products from the chamber 101 through the narrow central outlet 107, the tangential velocity of the whirling fluid mixture becomes essentially inversely proportional to the distance from the axis 103 due to conservation of angular momentum. The negative pressure gradient of the fluid mixture thus becomes inversely proportional to the third power of that distance. This property is extended all the way from the outlet 107 towards the window 105 just as a tornado is extended towards the earth's surface. Since the vortex flow is contained in the axially symmetrical chamber 101, the axes of symmetry of the vortex flow and of the chamber 101 tend to coincide. This is an example of the strong tendency towards two-dimensionality of flow that is observed in confined rotating fluids (see H.P. Greenspan, Theory of Rotating Fluids, Cambridge University Press, 1968, p. 3).

The secondary flow 113 does not participate in the vigorous whirling motion of the vortex flow as it is introduced into the chamber 101 in an

essentially radial direction and flows as a thin boundary layer 117 in direct contact with the non-rotating window 105. The strong radial pressure gradient produced by the whirling motion of the vortex flow is felt almost unchanged by the secondary flow 113. This fact is well known in the art (see G.K. Batchelor, Introduction to Fluid Flow Mechanics, Cambridge University Press, 1967, p. 315). In the absence of a centrifugal force to balance the negative radial pressure gradient, the secondary flow 113 is accelerated vigorously towards the centre 103 of the window 105, flowing as a high velocity thin boundary layer 117 on its surface until it is swallowed up at the centre 103 by a narrow "tornado" tube 119.

Without the described whirling effect, the secondary flow 113 would adhere to the window 105 only near the periphery 115 where it is injected, and as it would move towards the center 103 it would be slowed down and separated from the window 105. Therefore, keeping the window 105 protected by the secondary flow 113 without the above described whirling effect, would require a flowrate of secondary gas comparable to the primary gas flowrate, and the secondary flowrate required would get much greater as the diameter of the window 105 increases.

With the described whirling effect present in accordance with the present invention, the negative pressure gradient increases steeply towards the center 103 of the window 105, acting as an anchor to pull the secondary flow 113 from the periphery 115 to the center 103 without separation. The stabilizing effect of a negative pressure gradient on a boundary layer, preventing it from separating, is well known in the art (see Schlichting, Boundary Layer Theory, McGraw-Hill, 1995, p. 100). Thus using this effect for keeping the window 105 protected by the secondary flow 113, enables a secondary flowrate of only a few percent of the primary flowrate, essentially independent of the diameter of the window 105. Moreover, it was verified by experiment that in this flow

configuration, the flowrate of the secondary flow 113 does not have to be increased with increasing flowrate of the primary flow 109. On the contrary, increasing the flowrate of the whirling primary flow 109 enhances the negative radial pressure gradient adjacent the window 105 and this has a further stabilizing effect on the secondary flow 113.

It was determined by experiments that with the flow configuration characteristic of the present invention, in the case of the secondary flow 113 flowing at a rate of 0.5 *l*/min and of the primary flow 109 flowing at a rate exceeding 20 *l*/min, the secondary flow 113 completely adhered to a 60 mm diameter window 105 over its entire inner surface. The "tornado" tube 119 was attached to the window 105 at a central zone having a 3 mm diameter.

By virtue of the flow pattern characteristic of the present invention, the secondary flow 113 is not heated to the same extent as the primary flow 109 as it does not contact the chamber's periphery 116 to remove heat therefrom and its residence time in the chamber 101 is shorter than that of the primary flow 109. Furthermore, it is not heated by mixing with the primary flow 109 as they do not essentially mix, neither is it heated appreciably by the solar radiation 111 crossing the chamber 101 since it is not loaded with radiation absorbing particles.

The relatively small amount of the secondary flow 113 and its relatively low temperature are advantageous, as significantly less heat from the solar radiation 111 is absorbed thereby and lost, thus increasing the overall receiver yield. Moreover, the fact that the secondary flow 113 reaches a relatively low temperature may enable it to be an inert gas, a product of the reaction (hydrogen in the present embodiment), or even a heat sensitive component of the reaction (methane in the present embodiment).

The high velocity of the secondary flow 113 along the window 105 improves its protection against the possibility of particles clinging to the

window 105, and also improves the coefficient of heat transfer by convection therefrom to the secondary flow 113, thereby more effectively cooling the window 105.

Fig. 3 shows a solar receiver using a reactor chamber of the present invention as generally described above, but having additional features for improving the reactor's performance.

In Fig. 3, a solar receiver 300 has a longitudinal axis of symmetry 320, and comprises first 301 and second 302 axi-symmetric chambers separated from each other by a partition 303 which is provided with an outlet 304 located at its center. The receiver 300 is further provided with a transparent window 305 adapted for admitting concentrated solar radiation 111 into the first chamber 301. The receiver 300 is also provided with primary ingress means 307 for admitting a primary flow of methane and secondary ingress means 308 for introducing a secondary flow into the chamber 301. The primary means 307 comprise an annular passage 306, shaped so as to deliver the primary flow into the chamber 301 in a converging manner, directed away from the window 305. The primary ingress means 307 are also designed to impart to the primary flow a whirling motion around the longitudinal axis 320 of the chamber 301. For this purpose, the primary ingress means 307 may comprise the impeller-like ring 110 (shown in Fig. 2), or rather they may have any other suitable design. The secondary means 308 comprise an annular, preferably grooved passage 310 through which the secondary flow is delivered as an essentially radial flow into the chamber 301 along an inner periphery 318 of the transparent window 305.

The initial widening of chamber 301 in the flow direction of the primary flow renders the chamber's diameter larger than the window's diameter and, thereby, makes the chamber's shape closely approximate a black body radiation cavity.

The solar receiver 300 further has a solar concentrator 335 mounted adjacent the window 305 to direct the incident solar radiation 111 into the chamber 301. In order to allow for a wide scattering angle of solar radiation 111 entering the chamber 301, a ceiling portion 319 of the chamber 301 may be thin and thus poorly insulated. Accordingly, the primary ingress means 307 are designed so that the primary flow is introduced into the chamber 301 after absorbing heat from the poorly insulated ceiling portion 319. The absorbed heat is thus recycled into the chamber 301.

A third ingress means (not shown) may be mounted in close proximity to the window 305 and external thereto in order to provide an external cooling flow to the window 305, which may be, for example, essentially radial or tangential.

The reaction products, leaving the chamber 301 through the outlet 304, enter an additional chamber 302, where they are cooled by cooling means, for example, by sprays of water produced by nozzles 312, before entirely leaving the receiver 300. The reaction products leaving the receiver 300 may be delivered to any suitable downstream equipment, such as conventional separation equipment, heat exchanger or any other equipment as known *per se* in the art.

Figs. 4 to 7 show further features of the reaction chamber for improving the receiver's performance.

Fig. 4 shows another solar receiver 400 which is similar to the solar receiver 300, but which has primary ingress means 407 that are designed differently in that they discharge into the chamber 401 a divergent conical jet such that the whirling jet enters the chamber 401 along the chamber's interior surface 413. The immediate contact of the primary flow with the hot chamber surface 413 initiates the pyrolysis of methane and the formation of carbon particles, which serve as a very effective agent for absorption of solar radiation

and for almost instantaneous transmission of the absorbed heat to the gas in which the particles are suspended.

Fig. 5 shows a solar receiver 500 which may have a general design of either of the previous solar receivers 300 or 400, but which has an egress means in the form of a central pipe 515 that protrudes into the chamber 501 through the partition 503, thereby bringing the outlet 504 closer to the window 505. By virtue of this arrangement, the whirling motion pattern inside the chamber 501 may gain additional stability and may not be hampered by buoyancy effects that may be caused by inhomogeneous heating of the gas inside the chamber 501.

Fig. 6 shows a solar receiver 600 which may have a general design of any of the previous solar receivers 300, 400, or 500, but which has a refractory “flame holder”-type component 609 disposed inside the chamber 601 adjacent the primary ingress means 607, so as to absorb heat from the solar radiation and to heat the primary flow passing therethrough, whereby the reaction is initiated and a continuous production of heat absorbing carbon black particles is sustained.

Fig. 7 shows another solar receiver 700 which is similar to the solar receiver 300, but which has a reaction chamber 701 with a tapering surface 713 such that the whirling primary flow enters the chamber 701 along the chamber’s hot interior surface 713, initiating the reaction. A chamber 701 of this shape may be advantageous when a shorter residence time is required.

While the invention has been described with respect to preferred embodiments, it will be appreciated that many variations, modifications and other applications of the invention can be made. Particularly, the internal arrangement of the reaction chamber, the overall design of its components, in particular of the transparent window, the primary and secondary ingress means, the egress means and the downstream chamber, may vary, as long as they

provide for the primary and secondary flows and their interaction in accordance with the present invention.

CLAIMS:

1. A method for protecting a surface at one end of a reaction chamber having a longitudinal axis transverse to said surface and having a periphery radially remote from said axis, said surface having an inner area close to said axis and an outer periphery radially remote from said axis, the method comprising introducing a primary flow of reactants into the chamber in a manner whirling around said longitudinal axis, and withdrawing reaction products at an opposite end of the reaction chamber in a flow along the longitudinal axis, whereby said primary flow and said flow of reaction products approximate a free vortex flow which creates a pressure gradient, where the pressure is highest at the periphery of the chamber and lowest in the vicinity of the longitudinal axis, and introducing at said outer periphery of said surface a secondary protecting flow and directing it in said chamber towards said central area, whereby said pressure gradient of the vortex flow keeps said secondary flow adjacent said surface substantially over its entire area and, consequently, prevents said surface from contact with said primary flow and said flow of reaction products.

2. A method according to Claim 1, wherein said secondary flow is introduced in the chamber at a flow rate lower than that of the primary flow.

3. A method according to Claim 1 or 2, wherein said secondary flow may be free of any said reactants of the primary flow.

4. A method according to Claim 1, 2 or 3, wherein said primary flow comprises a working fluid and said secondary flow is free of said working fluid.

5. A method according to any one of Claims 1 to 4, whereby said secondary flow is used to cool said surface.

6. A method according to any one of Claims 1 to 5, whereby said primary flow is introduced into the chamber as a conical whirling jet flowing away from

said surface.

7. A method according to any one of Claims 1 to 6, whereby said primary flow is introduced into the chamber along an interior wall thereof.

8. A method according to any one of Claims 1 to 7, whereby radiation absorbing particles are introduced into the chamber in order to elevate said primary flow's temperature and thereby initiate the reaction.

9. A reaction chamber having a longitudinal axis and a periphery radially remote from said axis, a surface to be protected disposed at one end of the chamber and orientated substantially transversely to said longitudinal axis, said surface having an inner area close to said axis and an outer periphery radially remote from said axis, a primary ingress means adapted for introducing into the chamber a primary flow of reactants in a manner whirling around said longitudinal axis, an egress opening disposed at an opposite end of the chamber adapted for withdrawing reaction products from the chamber in a flow along said longitudinal axis, whereby said primary flow and said flow of reaction products approximate a free vortex flow which creates a pressure gradient, where the pressure is highest at the periphery of the chamber and lowest in the vicinity of the longitudinal axis, and a secondary ingress means adapted for introducing at said outer periphery of said surface a secondary protecting flow and directing it in said chamber towards said central area, whereby said pressure gradient of the vortex flow keeps said secondary flow adjacent said surface substantially over its entire area and, consequently, prevents said surface from contact with said primary flow and said flow of reaction products.

10. A reaction chamber according to Claim 9, wherein the longitudinal axis passes through said egress opening.

11. A reaction chamber according to Claim 9 or 10, wherein the reaction chamber is part of a volumetric solar receiver and the surface to be protected is a transparent window of said solar receiver adapted for admitting incident concentrated solar radiation.

12. A reaction chamber according to Claim 11, capable of being associated with a solar radiation concentrator via said transparent window.

13. A reaction chamber according to Claim 11, wherein said reaction chamber is shaped to approximate a black body radiation cavity.

14. A reaction chamber according to any one of Claims 9 to 13, wherein said chamber has walls that are capable of being heated up, and said primary ingress means are arranged so that said primary flow acts to extract heat from said walls prior to being introduced into said chamber.

15. A reaction chamber according to any one of Claims 9 to 14, further comprising means for introducing in the chamber refractory material disposed so as to heat said primary flow of reactants.

16. A reaction chamber according to any one of Claims 9 to 15, wherein said egress opening is axially extended towards said surface to be protected.

17. A reaction chamber according to any one of Claims 9 to 16, wherein said secondary ingress means are adapted for introducing in the chamber said secondary flow at a flow rate lower than that of the primary flow.

ABSTRACT

A reaction chamber has a surface to be protected and a longitudinal axis transverse to this surface. For the protection of the surface, a method is used comprising introducing a primary flow of reactants into the chamber in a manner whirling around the longitudinal axis thereof, withdrawing reaction products at an opposite end of the reaction chamber in a flow along the longitudinal axis, and introducing into the chamber a secondary protecting flow directed from a periphery of the surface towards the longitudinal axis. The primary flow and the flow of reaction products approximate a free vortex flow and a pressure created by this vortex flow keeps the secondary flow adjacent the surface to be protected, substantially over its entire area.

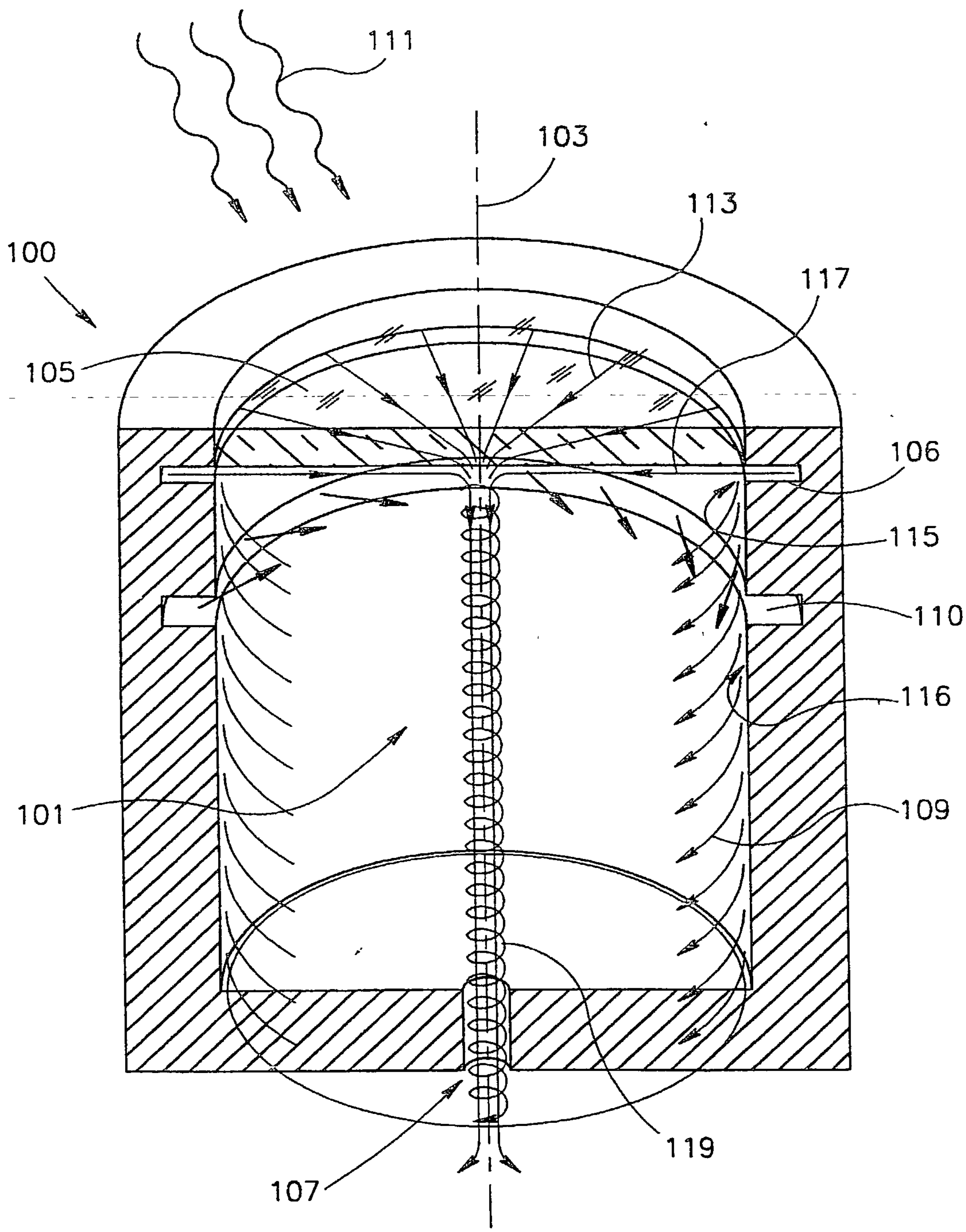

FIG.1

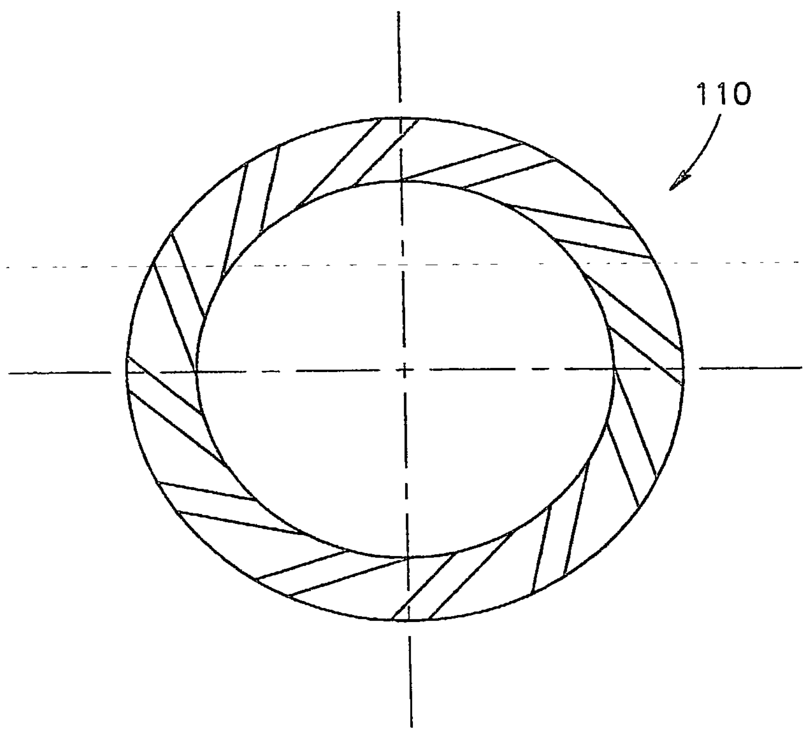

FIG.2

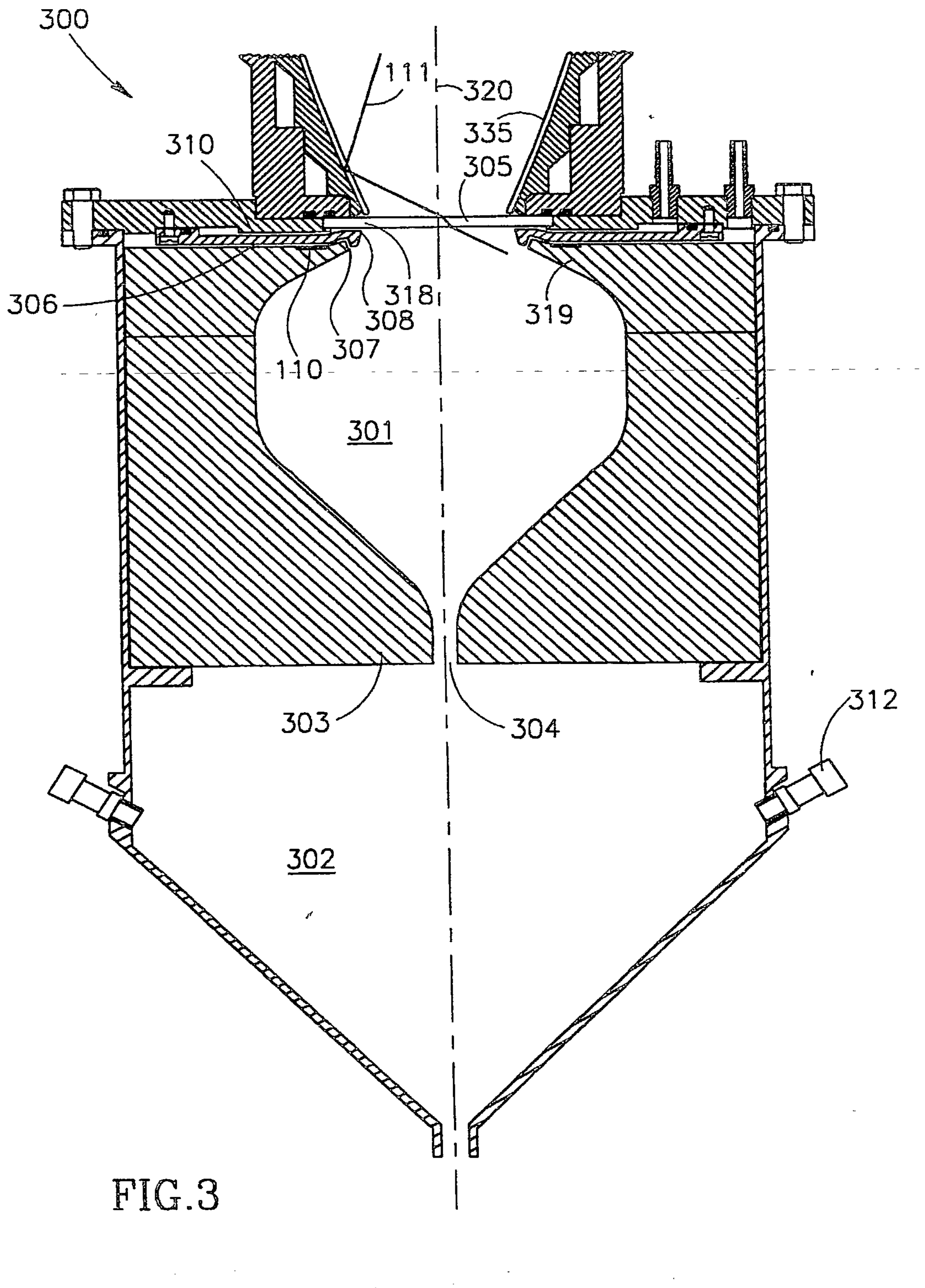
300
111
320
335
310
305
306
318
308
307
110
319
301
303
304
312
302

FIG.3

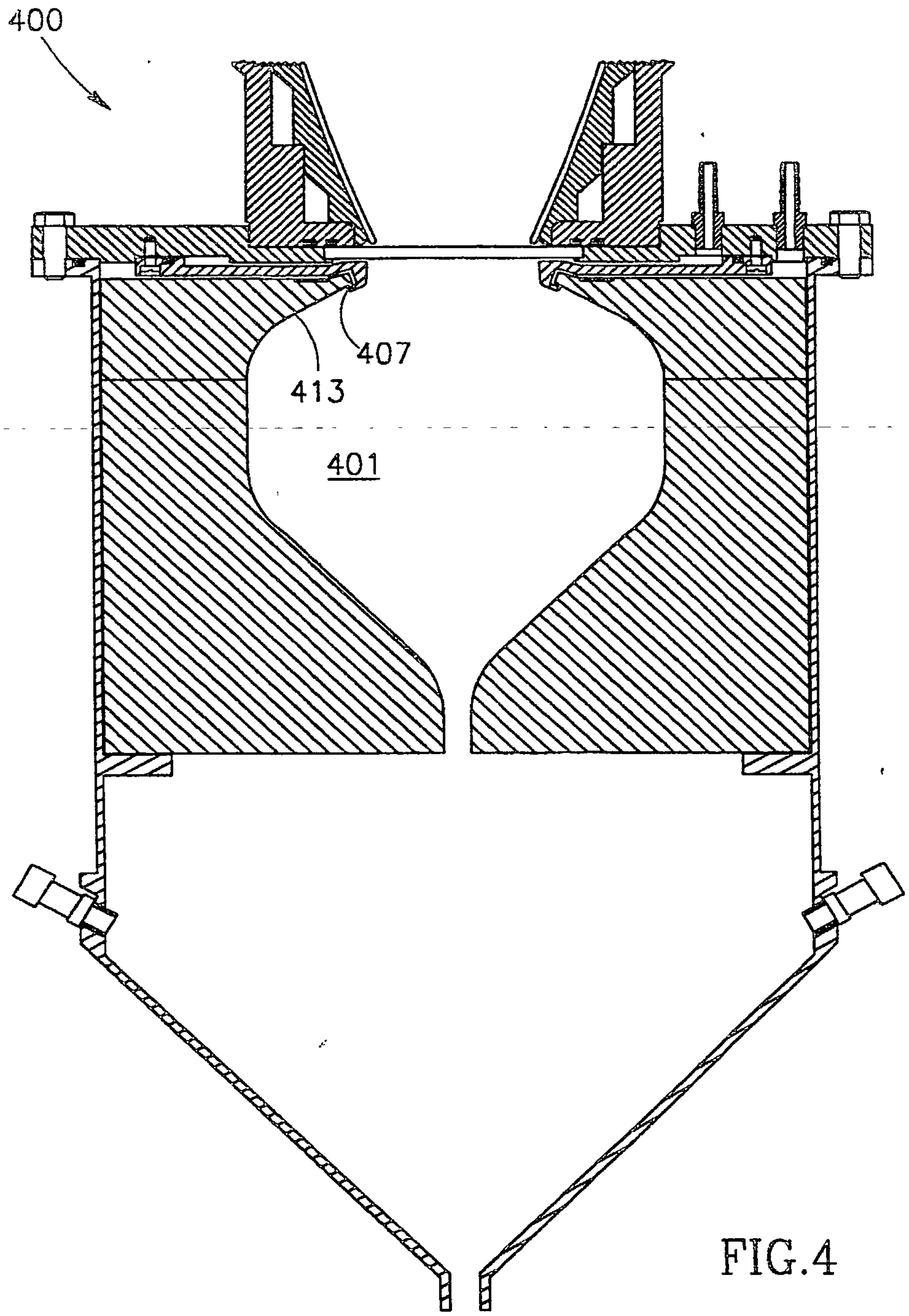

FIG.4

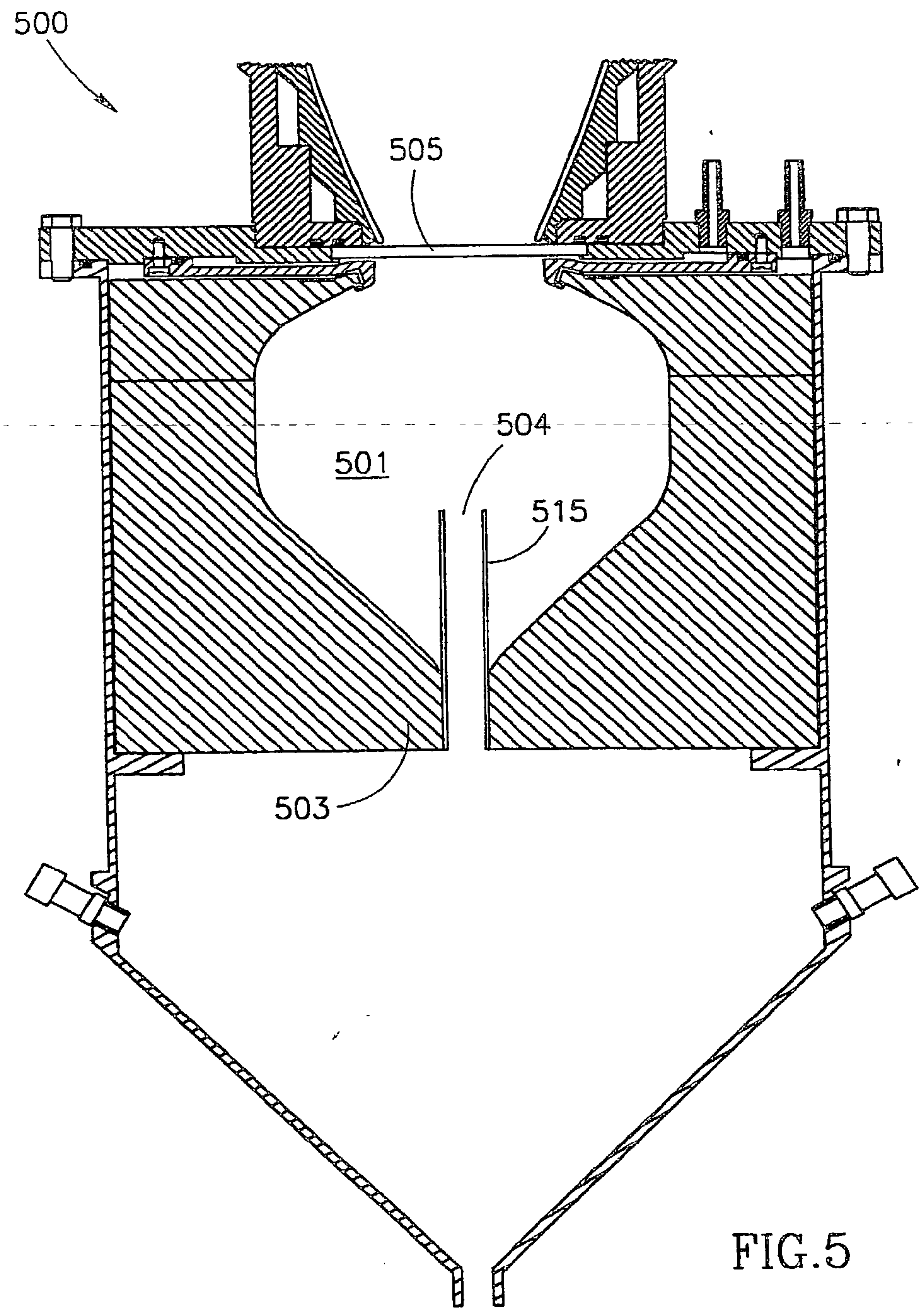

FIG.5

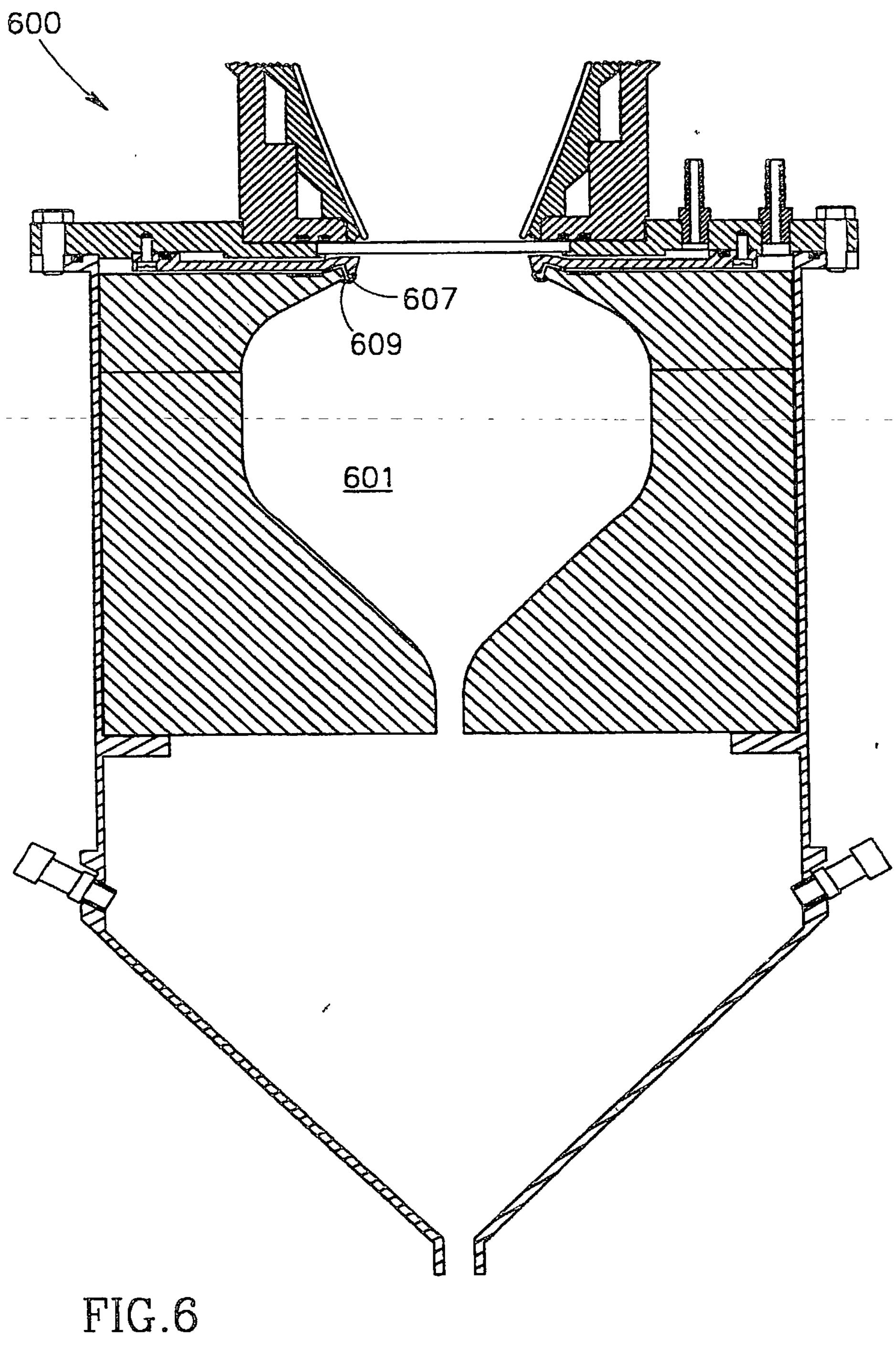

FIG.6

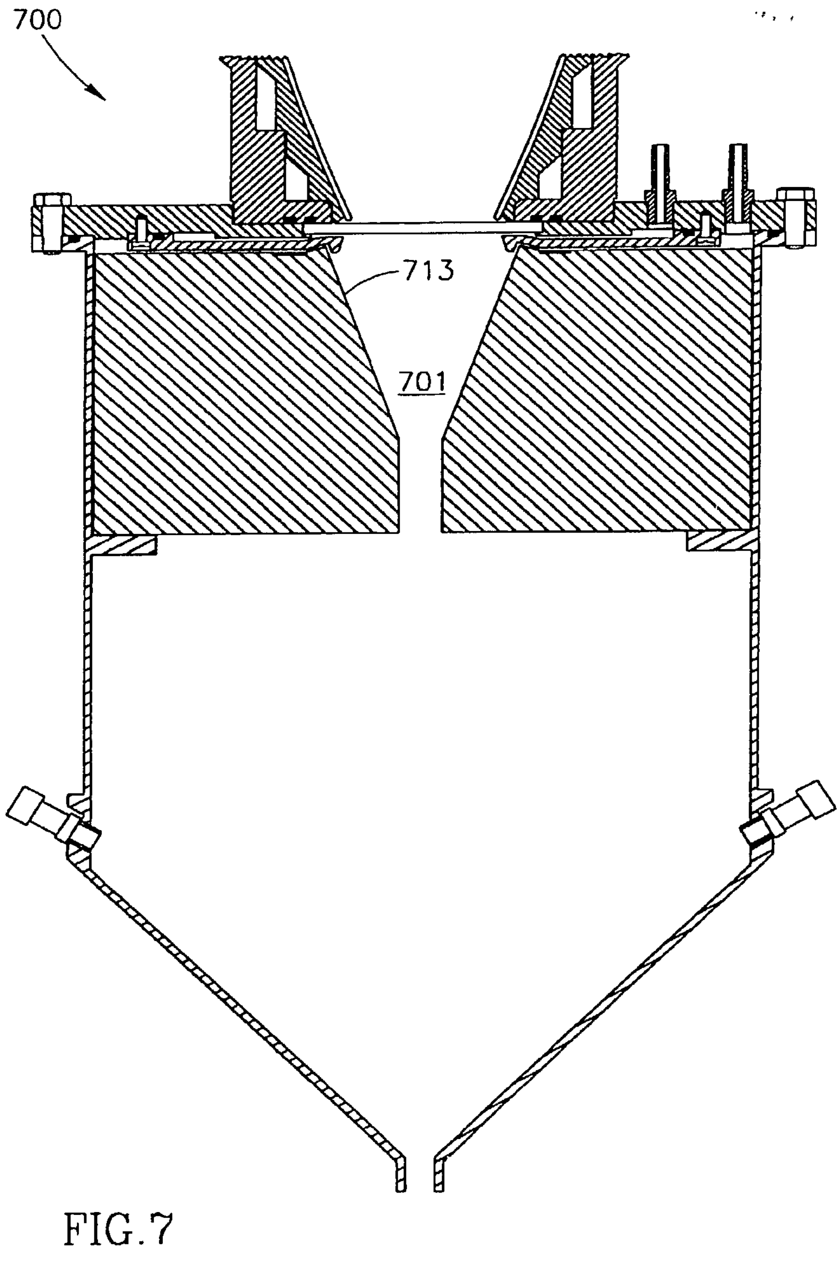

FIG.7

INVENTOR INFORMATION

Inventor One Given Name:: Abraham
Family Name:: KOGAN
Postal Address Line One:: Shaked
City:: DN Menashe
Country:: Israel
Postal or Zip Code:: 37862
Citizenship Country:: Israel
Inventor Two Given Name:: Meir
Family Name:: KOGAN
Postal Address Line One:: Yakinton Street 2
City:: Maalot
Country:: Israel
Postal or Zip Code:: 21520
Citizenship Country:: Israel

CORRESPONDENCE INFORMATION

Correspondence Customer Number:: 001444
Fax One:: 202-737-3528
Electronic Mail One:: Mail@BrowdyNeimark.com

APPLICATION INFORMATION

Title Line One:: REACTION CHAMBER WITH A PROTECTED SURFAC
Title Line Two:: E
Total Drawing Sheets:: 7
Formal Drawings?:: Yes
Docket Number:: KOGAN=4
Secrecy Order in Parent Appl.?:: No

REPRESENTATIVE INFORMATION

Representative Customer Number:: 1444

CONTINUITY INFORMATION

This application is a:: 371 OF
> Application One:: PCT/IL00/00483
Filing Date:: 08-08-2000

PRIOR FOREIGN APPLICATIONS

Foreign Application One:: 1313714
Filing Date:: 08-12-1999
Country:: Israel
Priority Claimed:: Yes

Source:: PrintEFS Version 1.0.1

Combined Declaration for Patent Application and Power of Attorney

As a below-named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below next to my name; and that I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled

REACTION CHAMBER WITH A PROTECTED SURFACE

the specification of which (check one)

☒ is attached hereto;

☐ was filed in the United States under 35 U.S.C. §111 on ________, as U.S. Appln. No. ________*; or

☐ was/will be filed in the U.S. under 35 U.S.C. §371 by entry into the U.S. national stage of an international (PCT) application, PCT/________; filed ________, entry requested on ________*; national stage application received U.S. Appln. No. ________*; §371/§102(e) date ________* (* if known)

and was amended on ________ (if applicable).
(include dates of amendments under PCT Art. 19 and 34 if PCT)

I have reviewed and understand the contents of the above-identified specification, including the claims, as amended by any amendment referred to above; and I acknowledge the duty to disclose to the Patent and Trademark Office (PTO) all information known by me to be material to patentability as defined in 37 C.F.R. §1.56.

I hereby claim foreign priority benefits under 35 U.S.C. §§ 119 (a)-(d) and 365 (b) of any prior foreign application(s) for patent, inventor's or plant breeder's rights certificate(s), or under §365(a) of any PCT application which designated at least one country other than the U.S., listed below:

Application No.	Country	Filing Date (MM/DD/YYYY)
131371	Israel	12 August 1999

If I claimed foreign priority above, I hereby identify below any foreign application for patent (including an international (PCT) application designating a country other than the United States) or for an inventor's or plant breeder's certificate, having a filing date before that of the earliest application from which foreign priority is claimed (if left blank, then there are none):

Non-Priority Application No.	Country	Filing Date (MM/DD/YYYY)

I hereby claim the benefit under 35 U.S.C. §119(e) of any United States provisional applications listed below:

Application No	Filing Date (MM/DD/YYYY)

I hereby claim the benefit under 35 U.S.C. §120 of any prior U.S. non-provisional application(s) or under §365(c) of any prior PCT international application(s) designating the U.S., listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in such U.S. or PCT international application in the manner provided by the first paragraph of 35 U.S.C. §112, I acknowledge the duty to disclose to the PTO all information which is material to patentability as defined in 37 C.F.R. §1.56 which became available between the filing date of the prior application and the national or PCT international filing date of this application:

Application No.	Filing Date (MM/DD/YYYY)	Status (patented, pending, abandoned)

As a named inventor, I hereby appoint the following registered practitioners to prosecute this application and to transact all business in the Patent and Trademark Office connected therewith:

All of the practitioners associated with Customer Number 001444

Direct all correspondence to the address associated with **Customer Number 001444**, which is presently:

BROWDY AND NEIMARK, P.L.L.C.
624 Ninth Street, N.W.
Washington, D.C. 20001-5303
(202) 628-5197

 Atty. Docket: :

Title: REACTION CHAMBER WITH A PROTECTED SURFACE

U.S. Application filed ______________, Serial No. ________

PCT Application filed 8 August 2000, Serial No. PCT/IL00/00483

The undersigned hereby authorizes the U.S. Attorneys or Agents appointed herein to accept and follow instructions from Reinhold Cohn and Partners as to any action to be taken in the U.S. Patent and Trademark Office regarding this application without direct communication between the U.S. Attorneys or Agents and the undersigned. In the event of a change of the persons from whom instructions may be taken, the U.S. Attorneys or Agents appointed herein will be so notified by the undersigned.

I hereby further declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under 18 U.S.C. §1001 and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

1-00

FULL NAME OF FIRST INVENTOR	INVENTOR'S SIGNATURE	DATE
KOGAN Abraham	A. Kogan	4.8.2002
RESIDENCE		CITIZENSHIP
Shaked, D.N. Menashe 37862 ILX		Israeli
POST OFFICE ADDRESS		
Shaked, D.N. Menashe 37862		

2-00

FULL NAME OF SECOND INVENTOR	INVENTOR'S SIGNATURE	DATE
KOGAN Meir	M. Kogan	4.8.2002
RESIDENCE		CITIZENSHIP
2 Yakinton Street, Maalot 21520 ILX		Israeli
POST OFFICE ADDRESS		
2 Yakinton Street, Maalot 21520		

FULL NAME OF THIRD INVENTOR	INVENTOR'S SIGNATURE	DATE
RESIDENCE		CITIZENSHIP
POST OFFICE ADDRESS		

FULL NAME OF FOURTH INVENTOR	INVENTOR'S SIGNATURE	DATE
RESIDENCE		CITIZENSHIP
POST OFFICE ADDRESS		

FULL NAME OF FIFTH INVENTOR	INVENTOR'S SIGNATURE	DATE
RESIDENCE		CITIZENSHIP
POST OFFICE ADDRESS		

FULL NAME OF SIXTH INVENTOR	INVENTOR'S SIGNATURE	DATE
RESIDENCE		CITIZENSHIP
POST OFFICE ADDRESS		

ALL INVENTORS MUST REVIEW APPLICATION AND DECLARATION BEFORE SIGNING ALL ALTERATIONS MUST BE INITIALED AND DATED BY ALL INVENTORS PRIOR TO EXECUTION. NO ALTERATIONS CAN BE MADE AFTER THE DECLARATION IS SIGNED. ALL PAGES OF DECLARATION MUST BE SEEN BY ALL INVENTORS.